CHARACTERIZATION OF METAL ON ELASTOMER VERTICAL INTERCONNECTIONS

François Colomb, Kevin Eastman, and John Roman

Raytheon Company
Advanced Device Center
362 Lowell Street
Andover, MA 01810
(508) 470-9402 (off.), (508) 470-9345 (FAX)

ABSTRACT

A metal on elastomer vertical interconnection for multilayer microwave modules is presented. Measured insertion loss is 0.5 dB at 6 GHz. Layer to layer lateral misalignment of the substrates by as much as ±0.006 inch causes only a 0.1 dB degradation in performance. A two-tier design approach is presented for first analyzing the vertical strips as a uniform multiconductor transmission line and then for including the interactions of all discontinuities in a 3D simulation using the finite element method.

INTRODUCTION

Multilayer microwave circuits are of considerable interest for commercial and military applications requiring low profile subassemblies such as airborne and satellite phased arrays. Key to this technology is the ability to provide low insertion loss interconnections between layers for DC, digital, and RF signals. Discrete connectors both from-the-shelf and custom made are cumbersome and costly even for a relatively low number of interconnections per subassembly.

Metal on elastomer interconnections are based on a widely different approach, see Figure 1. A single elastomer piece with embedded gold strips provides a large array of vertical conductors that can be used to form several connections. The electrical cross-section of each interconnection is established by defining appropriate contact pads on the substrates. This results in a short multiconductor transmission line where bundles of strips are excited against other bun-

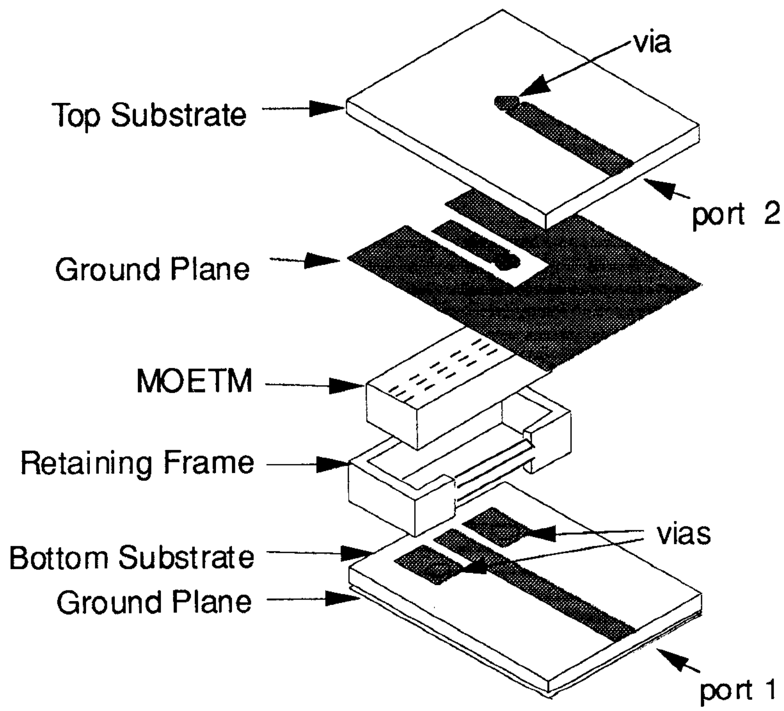

Figure 1. Metal on elastomer vertical interconnection of two substrates with microstrip based layout.

0-7803-3246-6/96/$5.00 © IEEE

dles. Unconnected strips and strips that connect only one pad at either end create parasitics that play an important role especially in determining the bandwidth of the interconnection.

ANALYSIS

The design approach consists in first determining ground-signal-ground (GSG) contact patterns that produce a vertical transmission line with approximately the same characteristic impedance as the feedlines leading to the vertical interconnection. A program based on the static approximation was developed for calculating transmission line parameters of uniform multiconductor lines. It is based on the integral equation that results from subjecting the electric field potential obtained from Poisson's equation to the appropriate boundary conditions on the conductors. The charge distribution of each strip is expanded into a linear combination of two inverse Maxwell basis functions (one with even symmetry and the other with odd symmetry) and Galerkin's technique is used to determine the unknown amplitude coefficients. The characteristic impedance of the multiconductor line is then determined from the capacitance between the center bundle of strips and the two outer bundles.

The second part of the design approach consists in electromagnetic simulations of the interconnection of the two substrates using Sonnet from Sonnet Software and the 3D finite element simulator HFSS from Hewlett-Packard. The elastomers from Elastomeric Technologies used in this study have 4 sets of parallel strips. Although the strips of each set are on a constant pitch, the 4 sets are not aligned in any predetermined way during the manufacturing process. This semi-random distribution of the strips is taken into account by associating a random number with uniform probability distribution to the position of each set. For a given contact pad design, a number of test cases are then generated and the simulated results are used to assess the distribution of the performance that could be expected in practice.

TEST FIXTURE

The fixture allows one to quickly interchange the substrates and to intentionally misalign the top and bottom substrates laterally in increments of 0.001 inch. The fixture can also accommodate two vertical interconnections for measuring the isolation between a pair of interconnections sharing the same elastomer.

RESULTS AND DISCUSSION

The method of moment for determining the characteristic impedance of uniform multiconductor transmission lines has been validated by analyzing simple structures such as a boxed balanced stripline for which there exist formulas in the literature. Very good agreement was obtained. The program was then used for the design of the GSG contact pads on the top and bottom substrates.

Numerical 3D simulations indicate that the insertion loss of the interconnection is characterized by a smooth in-band ripple and a sharp cutoff near 12 GHz. Simulated results for several semi-random distributions of the vertical strips of a particular GSG contact pad design are shown in Figure 2. Predicted in-band insertion loss is less than 0.5 dB.

Measured S-parameters for a slightly different transition are shown in Figure 3 and confirm qualitatively the predicted behavior. A sharper cut-off similar to that of Figure 2 occurs in some cases. The network analyzer was calibrated using the HP 3.5 mm OSLT cal kit thereby placing the reference planes at the connectors of the fixture. The interconnection insertion loss, adjusted for the loss of the feedlines, is shown versus frequency in Table I. The many small ripples and dips in the response are thought to be caused by small discontinuities in the 2 inch long

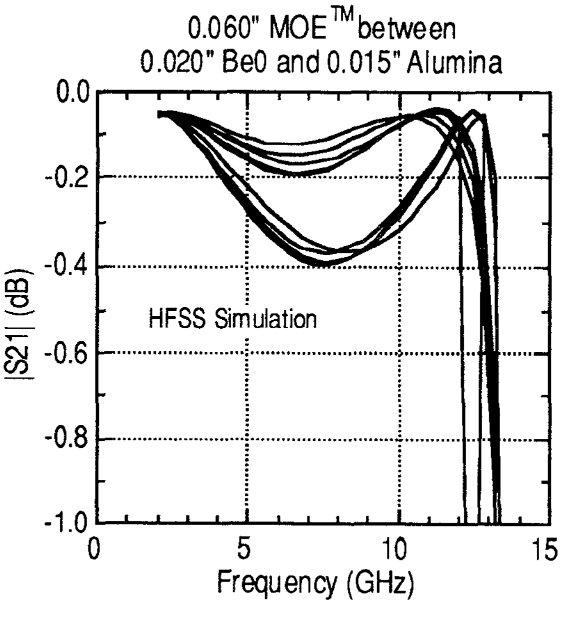

Figure 2. Simulated insertion loss of one interconnection design for 9 different strip distributions; shift between sets of rows obtained from random number generator with uniform probability distribution.

Table I. Measured insertion loss of vertical interconnection obtained by subtracting the loss of the feedlines measured separately.

	2 GHz	6 GHz	10 GHz	14 GHz	18 GHz
Interconnection & Feedlines (Figure 3)	0.8 dB	1.5 dB	2.3 dB	4.2 dB	6.6 dB
Feedlines	0.7 dB	1.1 dB	1.4 dB	2.0 dB	2.4 dB
Interconnection Alone	0.1 dB	0.4 dB	0.9 dB	2.2 dB	4.2 dB

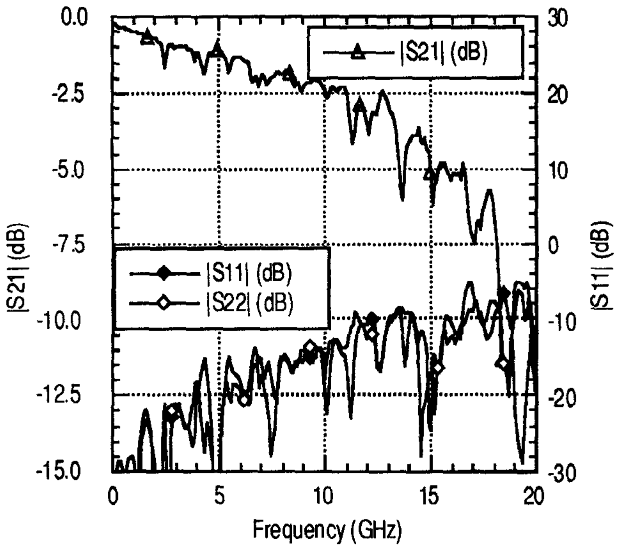

Figure 3. Magnitude of measured S-parameters of vertical interconnection including input and output microstrip feedlines.

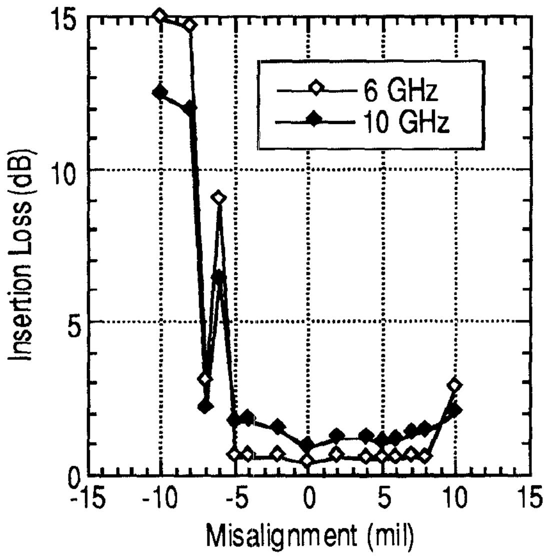

Figure 4. Measured insertion loss versus lateral misalignment of the top and bottom substrates at 6 GHz and 10 GHz.

microstrip lines and the connectors.

An example of the effect of lateral misalignments of the substrates is shown in Figure 4. The elastomer and the top substrate were displaced together perpendicularly to the microstrip lines while the bottom substrate was kept fixed. Misalignment by as much as ±0.006 inch from perfect alignment introduces a 0.1 dB degradation in insertion loss at 6 GHz and 0.8 dB at 10 GHz.

CONCLUSION

The metal on elastomer vertical interconnections tested in this study have a low pass frequency response with a smooth in-band insertion loss and a cut-off between 12 GHz and 14 GHz. Mid-band insertion loss is typically 0.5 dB. The interconnection is very tolerant of misalignment in the lateral direction perpendicular to the microstrip feedlines. The results presented here are part of an ongoing program and are not meant to be interpreted as ultimate performance.

ACKNOWLEDGMENTS

The authors would like to thank K. O'Shea and E. Tamuzzer from Raytheon Company for early concept discussions and improvements to the layout of the substrates.